Ultra-Long Duration Balloon (ULDB) Flight Software Requirements and Functional Specifications

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Submitted by:

Dwayne R. Morgan **Date**
Real Time Software Engineering Branch/Code 584

Roger Mason **Date**
Real Time Software Engineering Branch/Code584

Approved by:

Dave Stuchlik **Date**
Balloon Program Office/Code 820

Steve Smith **Date**
Balloon Program Office/Code 820

Concurrence:

Thomas J. Pittman **Date**
Real Time Software Engineering Branch/Code 584

Pam Pittman **Date**
Advanced Architectures and Automation Branch/Code 588

Change Information Page

Version	Date	Description	Affected Pages
1.0	10/01/1998	Original.	All
1.1	11/02/1998	Changed 2HDD to 1 HDD with the capability to daisy chain to 2 HDD. FSW-GEN-00130:	2
1.1	11/02/1998	Changed flight CPU boot locations from 3 to 2. FSW-GEN-00235:	2
1.1	11/02/1998	GPS reference changed to GPS ADU. GPS ADU data shall be switchable between both flight CPUs. FSW-DAT-02120, FSW-DAT-00460 TDRSS ACU data made switchable between flight CPUs. FSW-DAT-03110	3, 4, 5, 9 & 11
1.1	11/02/1998	All references to PCU changed to PDU. FSW-DAT-02110, FSW-CMD-00740, FSW-CMD-00820	3, 8 & 11
1.1	11/02/1998	Eliminate Science requirement for an RS-232 port as a backup to the 1553B interface for science housekeeping and science data. FSW-DAT-01120	3
1.1	11/02/1998	Added requirement for the flight computers to obtain status information from the TDRSS antenna control unit (ACU) via an RS-232 port. FSW-DAT-03120	4
1.1	11/02/1998	FIFO Board reference changed to TDRSS Data Interface board. FSW-DAT-00420	2, 5 & 11
1.11	12/15/1998	Data written to Non-volatile RAM (NVRAM) instead of RAM. FSW-DAT-00310	4
1.11	12/15/1998	“at least” added to FSW-GEN-00235, References to two 4 channel UART cards changed to eleven UART ports.	1, 2, 5
1.11	12/15/1998	Last sentence of FSW-DAT-00420 changed to: …maximum continuous TDRSS downlink data rate of at least 50kbps, with 150kbps desired. FSW-DAT-00420	5

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1.0 Introduction

Recent advances in composite super-pressure balloon materials have greatly enhanced the prospects for very long duration balloon flights on Earth as well as possible use for planetary exploration. NASA is embarking on the development of technologies to support extended balloon missions lasting up to 100 days (~5 circumnavigations of the globe) above 99.9% of Earth's atmosphere.

The Ultra Long Duration Balloon (ULDB) objective is to develop a low cost, integrated, advanced, long duration balloon system which is technically feasible and within program cost constraints while maintaining the existing balloon program. The ULDB program is significantly different from the current balloon program in that the expected science return is significantly greater than current balloon missions. In other words, it is more than simply extending current experiments over a longer time period. This program also expects to use technologies currently available in the spacecraft missions and commercial arenas to improve performance while containing costs.

The purpose of the ULDB flight software effort is to process, monitor, and control data received and collected on the airborne instrumentation package. The flight software will facilitate all communications with the instruments on board and to the ground through continuous line of sight and over the horizon communications.

1.1 Purpose

The document describes the ULDB Flight Software requirements and functional specifications. It is intended to include a complete list of all the requirements in all of the functional areas for all ULDB Flight Software systems. It is expected that this document shall be the basis from which design decisions will be made.

1.2 Applicable Documents

1.2.1 Project Documentation

The following ULDB project documentation is applicable and/or related to this document.

ULDB Design-To Requirements Document, revision 2.0, December 3, 1997, http://www.wff.nasa.gov/~uldb/designreqmts.pdf

1.2.2 Subsystem Documentation

The following ULDB Flight Software specific documentation is applicable and/or related to this document:

ULDB Flight Software Development Management Plan
ULDB Flight Software Operations Concept

2.0 System Overview

The ULDB Flight Software shall operate from a fully redundant AMPRO PC-104 based flight computer system with a 1553B redundant bus and eleven UART ports. All science communications with the flight computer shall be 1553B oriented. The flight software shall poll all subsystems for data, package data into CCSDS serial communication downlinks, receive commands for execution and routing, archive data and perform any required calculations for the mission.

3.0 Flight Software Requirements and Functional Specifications

Four Flight Software functional areas have been defined to support ULDB missions. The defined functional areas may represent specialized software calculations required for mission support, or may combine data acquisition and commanding to support specific subsystem requirements. The functional areas are General System Functions, Data Handling, Commanding, and Miscellaneous Calculations.

3.1 General System Functions

This section specifies the ULDB general system functions of the flight software. The flight computer hardware, communication interfaces, integration and test, boot recycling and CPU functions will be included in this section

3.1.1 Flight Computer Hardware

The basic flight computer hardware is discussed in this section. A detailed look at the requirements of the flight computer hardware is described in the <TBD > document.

FSW-GEN-00110	There shall be two fully redundant flight computers, each containing an Intel 486 processor, and utilizing a PC-104 buss.
FSW-GEN-00120	There shall be at least eleven UART ports, a 1553B bus interface card, and a customized TDRSS Data interface card for serial streaming I and Q data to the TDRSS transceiver.
FSW-GEN-00130	Each flight computer shall utilize a minimum of 1 hard drive with the capability for daisy chained 2 hard drives for data, software operating system storage.

3.1.2 General System Requirements

The flight software will provide operating features that will increase dependability of the system.

FSW-GEN-00210	There shall be two redundant flight computers capable of simultaneous data logging.
FSW-GEN-00215	Both flight computers shall utilize the 1553B buss. One designated flight computer shall serve as the Bus Controller (BC). The remaining flight computer shall operate in the Remote Terminal (RT) mode.
FSW-GEN-00220	Both science processors shall be configured as RTs via the redundant 1553B buss.
FSW-GEN-00225	The RT flight computer shall receive a health status from the BC. The RT flight computer shall reconfigure itself to the BC in the event of a failure by the acting BC flight computer.
FSW-GEN-00230	There shall be a watchdog timer on each flight computer that will reboot the computer in the event of a software lockup condition. The flight software shall reset the watchdog timer periodically.
FSW-GEN-00235	There shall be provision made for at least 2 boot locations on each flight computer to protect against the possibility of software corruption and boot device failures.
FSW-GEN-00240	The software or BIOS shall provide automatic cycling between multiple boot locations.
FSW-GEN-00245	The flight software shall provide a serial communication capability for ground diagnostics and pre-flight operations.

FSW-GEN-00250	The flight computer hard drives shall remain in a powered down/power saving mode when data is not being accessed or written to them to conserve power and reduce heat production.

3.2 Data Handling

This section describes the acquisition, formatting, storage, and transfer of ballooncraft housekeeping data, science housekeeping data, and science data by the flight computer.

3.2.1 Data Acquisition

Data Acquisition performed by the flight computers will be collected from the science redundant flight processors, all housekeeping ballooncraft subsystems, and status indicators from the communication links.

FSW-DAT-00110	Flight software shall time-stamp all housekeeping data at the time the flight computer receives it.

3.2.1.1 Science Instruments

The science instruments described in this document refer to the science processors used for data processing, command and data acquisition.

FSW-DAT-01110	The flight computers shall obtain science housekeeping and science data from the redundant science instrument processors via 1553B bus.

3.2.1.2 Ballooncraft Subsystems

The flight computers will obtain ballooncraft AART data via RS-232 from the ballooncraft subsystems.

FSW-DAT-02110	The flight computers shall obtain ballooncraft housekeeping data from the System and Power Distribution Unit (PDU) stacks on the same AART RS-232 port.
FSW-DAT-02120	The flight computers shall obtain GMT time from the GPS ADU unit via an RS-232 port. It is desired to obtain absolute position and attitude (azimuth) from the GPS ADU unit via the same RS-232 port. GPS ADU data shall be made switchable between both flight computers in the event of a single a flight computer failure.
FSW-DAT-02130	The flight computers shall obtain ascent velocity from the GPS ADU unit for autoballasting calculations.
FSW-DAT-02140	The flight computers shall obtain housekeeping data from the Ballooncraft Rotator via an RS-232 port. Rotator data shall be made switchable between both flight computers in the event of a flight computer failure.
FSW-DAT-02150	The flight computers shall be capable of obtaining housekeeping data from Balloon Control Subsystems (CAP, Universal Terminate Package, ULDBV) via an AART line. Balloon Control Subsystem data shall be made switchable between both flight computers in the event of a flight computer failure.

3.2.1.3 Communication Subsystems

The flight computers will obtain status data from the communications devices.

FSW-DAT-03110	The flight computers shall obtain TDRSS transceiver status data via a 1553B interface. TDRSS ACU data shall be made switchable between both flight computers in the event of a flight computer failure.

FSW-DAT-03120	The flight computers shall obtain status information from the TDRSS antenna control unit (ACU) via an RS-232 port.
FSW-DAT-03130	The flight computers shall obtain INMARSAT terminal status data via an RS-232 port.
FSW-DAT-03140	The flight computers shall obtain ARGOS PTT transmitter status data via an RS-232 port.
FSW-DAT-03150	The ballooncraft Line of Site (LOS) transmitters shall be capable of flowing science and housekeeping data. A dedicated RS-232 port shall allow LOS data transmissions while a separate RS-232 port shall be provided for receiving LOS commands.

3.2.2 Data Formatting

The flight software is responsible for formatting all data for logging to hard drive and downlinking to ground telemetry.

FSW-DAT-00210	All housekeeping and science data to be logged to hard drive shall be in binary format and indexed by a 1ms time stamp received from GPS ADU.
FSW-DAT-00220	Flight software shall format science, science housekeeping and ballooncraft housekeeping data in CCSDS packets for downlink transmission to all communication links.
FSW-DAT-00230	Each CCSDS data packet shall contain 1ms resolution time stamp of packet creation.
FSW-DAT-00240	Each ARGOS PTT ID shall contain a separate CCSDS header and 1ms resolution time stamp. The remaining bytes shall be filled up with data for each ID.

3.2.3 Data Storage

Flight software will log science, science housekeeping, and ballooncraft housekeeping data.

FSW-DAT-00310	Data to be logged to hard drive shall be buffered or cached into NVRAM (Non-Volatile Read Access Memory) until 90% of NVRAM is filled. The NVRAM contents shall then be written to hard drive. In the event of a reboot or power failure, NVRAM contents shall be read and logged to hard drive.
FSW-DAT-00320	Flight software shall log all commands received to hard drive with a 1 ms time GMT stamp index obtained from GPS ADU.
FSW-DAT-00330	Flight software shall log all science data to hard drive with a 1 ms time stamp index obtained from GPS ADU.
FSW-DAT-00340	Flight software shall log all science housekeeping data to hard drive with a 1 ms time stamp index obtained from GPS ADU.
FSW-DAT-00350	Flight software shall log all ballooncraft housekeeping data to hard drive with a 1 ms time stamp index obtained from GPS ADU.

3.2.4 Data Transfer

Data Transfers will use the flight software to transfer data to all communication links via RS232, and science processors via a dedicated 1553B buss.

FSW-DAT-00410	Flight software on both flight computers shall transfer all science, science housekeeping, and ballooncraft housekeeping data formatted in CCSDS packets to the WFF-93 PCM Encoder's RS232 deck. This data transfer shall support the LOS data downlink transmission.
FSW-DAT-00420	Flight software shall transfer all science, science housekeeping, and ballooncraft housekeeping data to a customized TDRSS Data Interface board for TDRSS transmission. Data shall be transferred in a nature that supports a maximum continuous TDRSS downlink data rate of at least 50kbps, with 150kbps desired.
FSW-DAT-00430	Flight software shall transfer science housekeeping, and ballooncraft housekeeping data to the INMARSAT terminal in 15 minute transmission intervals.
FSW-DAT-00440	Flight software shall transfer science housekeeping, and ballooncraft housekeeping data to the ARGOS PTT for downlink transmissions.
FSW-DAT-00450	Playbacks shall utilize the GMT time stamp for indexing data from the hard disk drive.
FSW-DAT-00460	The flight computers shall forward GMT from ADU to the science CPUs in 1Hz intervals over the 1553B interface.
FSW-DAT-00470	The flight computers shall forward MKS pressure, gauge select and GPS ADU vertical velocity to the CAP via an AART line at 1Hz intervals during ascent and (TBD) Hz during float.

3.3 Commanding

Commanding functions provide the capability for the flight software to execute, route, echo, and archive commands to the ULDB balloon-craft, and its subsystems.

FSW-CMD-00010	All commands shall be categorized by the flight software as Science or ULDB.
FSW-CMD-00020	A backup command decoder shall be capable of decoding commands from TDRSS, INMARSAT and LOS in the format described under 3.3.1.

3.3.1 Command Format

The command format identifies the structure of commands for decoding and encoding by the flight software.

FSW-CMD-00110	The flight software shall encode and decode an 8-byte binary format for all commands sent and received by the flight computer.

3.3.1.1 Command Format Contents

The command format content contains the actual command format structure.

FSW-CMD-01110	There shall be two frame sync bytes, FA(hex) and F3(hex).

FSW-CMD-01120	There shall be a minimum of 1 byte for the balloon ID and routing address. The first four bits including the LSB shall be the routing address while the last 4 bits including the MSB shall be the balloon ID.
FSW-CMD-01130	There shall be 1 byte allocated for the ones complement of the balloon ID and routing address.
FSW-CMD-01140	There shall be 1 byte allocated for the AART address. The MSB must be high at all times.
FSW-CMD-01150	There shall be 1 byte allocated for the ones complement of the AART address. The MSB must be low at all times.
FSW-CMD-01160	There shall be 1 byte allocated for the AART command message also called the AART command select. The MSB must be low at all times.
FSW-CMD-01170	There shall be 1 byte allocated for the ones complement of the AART command message also called the AART command select. The MSB must be 1 at all times.

3.3.2 Command Communications

The flight software shall have the capability to transmit commands to the ULDB balloon-craft and instruments using multiple communication interfaces.

FSW-CMD-00210	The flight software shall process all received commands through asynchronous AART line(s). All transmitted commands shall communicate via an AART and/or 1553b bus.
FSW-CMD-00220	The Universal Terminate Package (UTP) shall have a command capability from the flight computer via an AART line.
FSW-CMD-00230	The CAP shall be commandable from the flight computer via an AART line.

3.3.2.1 Over the Horizon (OTH) Network Command Communications

OTH communications will serve as the main commanding link once the ballooncraft is not is line of site visibility. The OTH communication networks include INMARSAT, TDRSS, ARGOS and IRIDIUM.

FSW-CMD-01210	The flight software shall be capable of receiving commands via the Telemetry Data Relay Satellite System (TDRSS) network.
FSW-CMD-01220	The flight software shall be capable of receiving commands via the INMARSAT network.
FSW-CMD-01230	The INMARSAT command initialization file shall contain all the necessary commands required to initialize and startup the INAMRSAT terminal.
FSW-CMD-01240	The flight software shall be capable of receiving commands via the Iridium network (TBD).

3.3.2.2 Line of Site (LOS) Commanding

While the ballooncraft is in LOS visibility a separate set of transmitters and receivers are used to command the ballooncraft.

FSW-CMD-02210 The flight software shall be capable of receiving commands via the Line of Site (LOS) receivers.

3.3.3 Command Execution

The flight software will be capable of executing commands addressed to the flight computer via an asynchronous AART bus.

FSW-CMD-00310 The flight software shall perform error checking as listed in 3.3.4 prior to all command execution.

FSW-CMD-00320 The flight software shall execute commands addressed to the flight computer.

FSW-CMD-00330 The flight software shall follow the echo command format (3.3.7) for successful or unsuccessful command receipt confirmation back to the command originator.

FSW-CMD-00340 Mission critical commands as defined in the Project Data Base of the operation control center requirements document shall be given execution priority over all other commands.

3.3.4 Command Error Checking

The flight software performs error checking on all commands to help eliminate erroneous errors either from the transmission process or the originator.

FSW-CMD-00410 The flight software shall use the ones complement in the command format to identify any errors during command transmission.

FSW-CMD-00420 The flight software shall validate all commands and ensure that the commands accepted conform to the command format definition as stated in 3.3.1.

3.3.5 Command Receipt Verification

Command receipt verification verifies receipt of commands to ground telemetry.

FSW-CMD-00510 The flight software shall provide the capability to verify the receipt of real-time commands by ground telemetry.

FSW-CMD-00520 The flight software shall echo (3.3.6) to the command originator the status of each command received as successful or unsuccessful.

3.3.6 Command Echo

The flight software creates command echoes whenever a command has been received. This allows the originator to know the flight computer acknowledged the command and execution follows. Command echoes consist of a command counter, the command message/select, and the command AART source.

FSW-CMD-00610 The flight software command echo shall contain 1 byte of command counter information. The counter shall count up to 1 bytes worth of commands before resetting to 0. The command counter shall keep track of all commands received by the flight computer.

FSW-CMD-00620 The flight software command echo shall contain the same 1 byte command message/select as the last command received.

FSW-CMD-00630	The flight software command echo shall contain the same 1 byte address of the last command received. This address is the same address required to route commands through the AART bus for source identification.

3.3.7 Command Logging

All commands will be archived to hard disk for the purpose of playback commanding and flight data storage.

FSW-CMD-00710	All commands received by the flight computer shall be logged to RAM upon receipt. The flight computers shall wait for a routine write to disk command before issuing the write to the hard drive command.
FSW-CMD-00720	All data written to hard drive shall have a 1ms resolution time stamp for each line of data recorded. Playbacks shall index the time stamp for start and stop points.
FSW-CMD-00730	Commands addressed to the flight computer and science shall be logged a second time when processed or routed to the science subsystem.
FSW-CMD-00740	Commands addressed to the CAP, Universal Terminate Package (UTP), Science System stacks, Backup Command stack, Power Distribution Unit (PDU) stacks, ULDBV, and Rotator shall be logged once.

3.3.8 Command Routing

The command routing address identifies the subsystem the command needs to be sent to. Each subsystem with an AART buss shall be identified by a preprogrammed address unique to that subsystem.

FSW-CMD-00810	The entire 8-byte command packet shall be forwarded to the appropriate subsystem once the flight software receives a command packet whose routing ID matches that subsystem.
FSW-CMD-00820	Command routing locations shall include the flight computer, CAP, UTP, Science system stacks, Backup Command stack, PDU stacks, ULDBV and Rotator.
FSW-CMD-00830	The routing address shall be 4 bits in length in the command format yielding a total of 16 unique locations.

3.4 Miscellaneous Calculations

The flight software shall perform miscellaneous calculations as required for various communication and subsystems tasks. The subsystem requiring software calculations include the INMARSAT transceiver and the autoballaster.

3.4.1 Autoballaster

The flight software controls the dropping of ballast from the ballast hopper by means of an autoballaster function. Ballast is used to regulate the altitude of the balloon.

FSW-MSC-00110	The flight software shall use an automated ballasting function to maintain the ballooncraft within a specified altitude range throughout the duration of the mission.
FSW-MSC-00120	The autoballasting function shall manage the daily allotment of ballast from a configurable file, and keep a daily tally of how much ballast has been dropped

for that day. Ballast shall not be dropped if the daily tally equals or exceeds the daily allotment. The daily ballast tally shall be reset to 0 once the next solar noon occurs.

FSW-MSC-00130 The autoballasting function shall recognizing a day as local solar noon to local solar noon as determined by GMT and GPS ADU position.

3.4.1.1 Autoballasting Configurability

FSW-MSC-01110 The autoballasting algorithm shall use a maximum of 3 MKS pressure sensors at any one time to derive an average pressure reading and compare this to the specified altitude range. This function shall be user configurable.

FSW-MSC-01120 Autoballasting shall not be activated until the ballooncraft has transcended the activation pressure threshold above which ballasting is disabled. The activation pressure threshold shall be user configurable.

FSW-MSC-01130 The amount of time the autoballasting algorithm has between ballast drops, and the number of seconds the ballast valve is allowed to open in a day shall be user configurable.

3.4.1.2 Autoballasting Status and Log files

FSW-MSC-02110 A status file shall be used to identify the current parameter settings of the autoballster. This file shall be used for resetting the autoballaster in the event of a reboot. The ballast configuration file shall be used in the event the autoballasting status file is not available at the time of reboot.

FSW-MSC-02120 A pressure log on hard drive shall be kept every 10 seconds of the average MKS pressure in mbars. This log shall have a minimum of the time of day, pressure (mbars) and the MKS sensor.

FSW-MWC-02130 A ballast log shall be kept of all ballast drops and/or changes to the autoballast status. The ballast log shall have a minimum of the following information: time of day, last MKS sensor read, pressure (mbars), active high altitude sensor, active mid altitude sensor, low altitude pressure boundary (mbars), high altitude pressure boundary (mbars), wait time (seconds), daily ballast limit (seconds), initial ballast drop amount, new day reset, total ballast dropped today (seconds), longitude (degrees), day change method (software startup, solar noon occurred, day reset via command), last local solar time, day (same or new), activation threshold (mbars).

3.4.2 INMARSAT Satellite Selection Algorithm

The flight software uses the INMARSAT satellite selection algorithm to determine the best look angle for communicating with the INMARSAT satellite network.

FSW-MSC-00210 The INMARSAT satellite selection algorithm (ISSA) shall select the highest elevation satellite by using a configurable ASCII file to ingest data.

FSW-MSC-00220 The ISSA shall use GPS ADU position and altitude of the ballooncraft and the latest satellite ephemeral from a configurable ASCII file to compute the highest visible INMARSAT satellite within a given ocean region.

4.0 References

The following documents are considered reference materials with have relevancy to this document.

NASA Systems Engineering Handbook SP-6105

Manager's Handbook for Software Development NASA ID: SEL-84-101

Ultra Long Duration Balloon (ULDB) Program Study: Interim Report (Polidan Study):

The Ultra Long Duration Balloon Project Design-To Requirements Document version 2.1

http://lheawww.gsfc.nasa.gov/docs/balloon/ULDB_study/DAYBAL_4.html

Acronyms

AART	Addressable Asynchronous Receive Transmit
ACU	Antenna Control Unit
ADU	Attitude Distribution Unit
BC	Bus Controller
CAP	Commandable Apex Package
CCSDS	Consultative Committee for Space Data Systems
CPU	Central Processing Unit
GB	Gigabyte
GMT	Greenwich Mean Time
GPS	Global Positioning System
FIFO	First In First Out
ID	Identification
IRIG	Inter-range instrumentation group
ISSA	INMARSAT Satellite Selection Algorithm
Kbps	Kilobits per second
LDB	Long Duration Balloon
LSB	Least Significant Bit
LOS	Line of sight
ms	Milli-Seconds
MSB	Most Significant Bit
NASA	National Aeronautics and Space Administration
OTH	Over the Horizon
PCM	Pulse Code Modulation
PDU	Power Distribution Unit
PTT	Platform Transmit Terminal
RT	Remote Terminal
RAM	Read Access Memory
SN	Space Network
TBD	To be determined
TDRSS	Tracking and Data Relay Satellite System
UART	Universal Asynchronous Receive Transmit
ULDB	Ultra Long Duration Balloon
ULDBV	Ultra Long Duration Balloon
UTP	Universal Terminate Package